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Regional Differences in Biomechanical Properties of the Ascending Aorta in Aneurysmal and Normal Aortas

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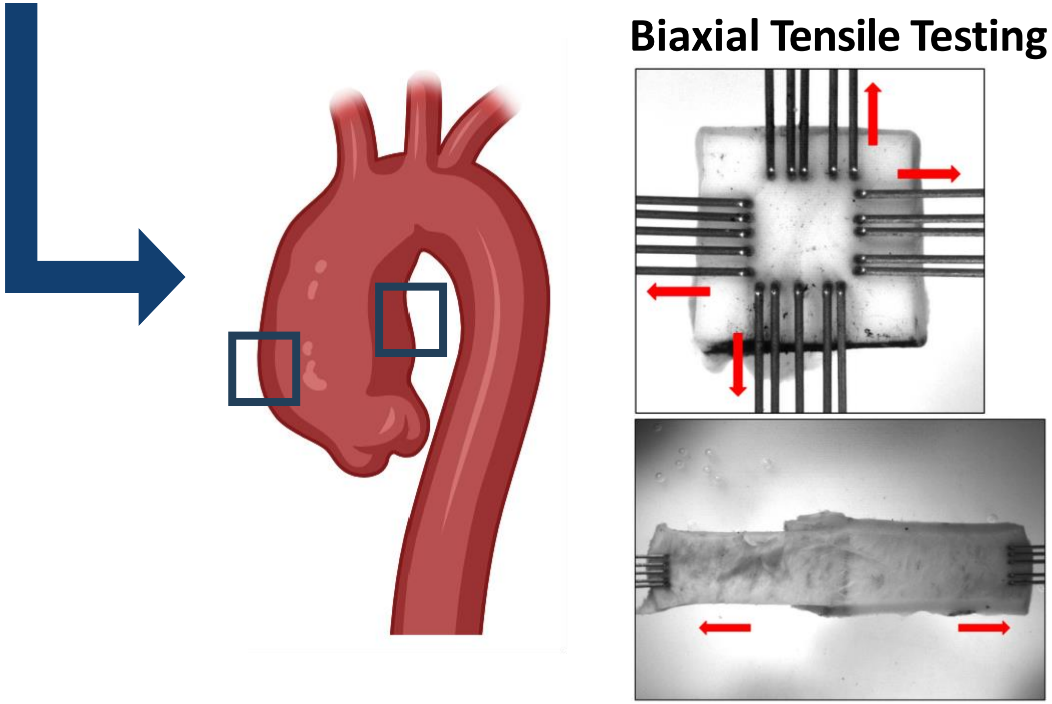
Background

- Aortic biomechanics can provide patient-specific measure of fragility of aortic tissue.
- However, many in vivo measures of aortic biomechanics consider the ascending aorta as having uniform material properties.
- Whether this approach is valid depends on regional biomechanical characteristics of the ascending aorta – but these are not well understood.

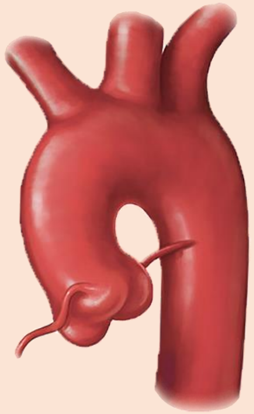
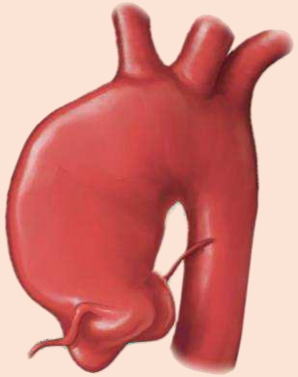
Objectives

- Evaluate ex-vivo biomechanical differences between the inner (IC) and outer (OC) curvature of aneurysmal and normal ascending aortas.

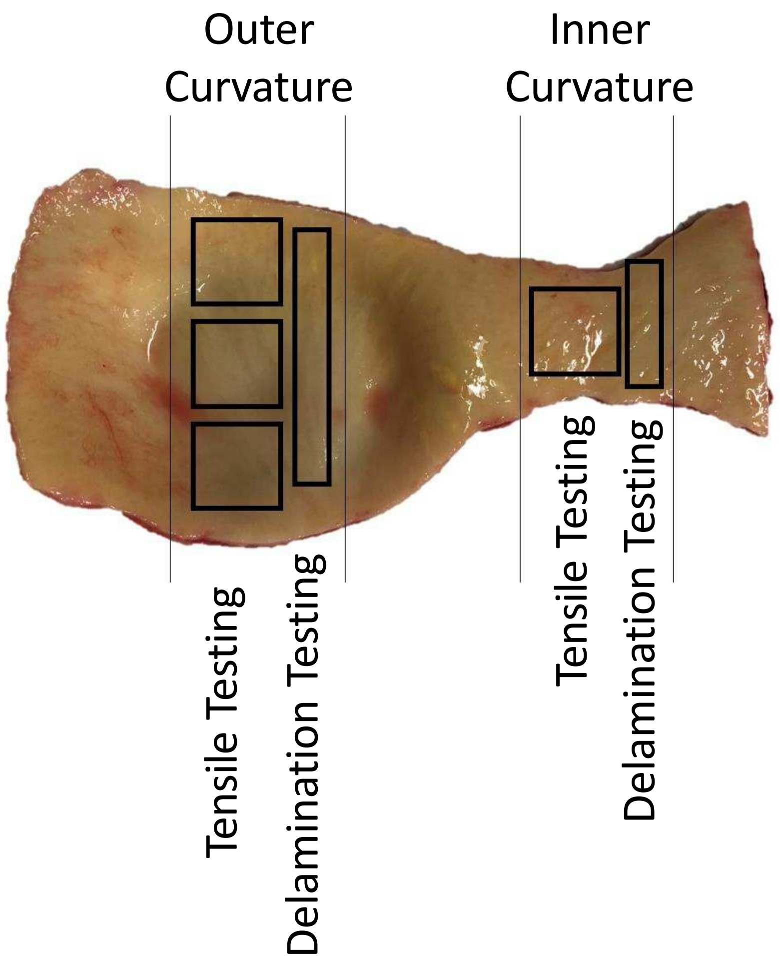
- Evaluate the association of clinical markers (i.e., age, asymmetric dilation) with presence of increased regional biomechanical differences.



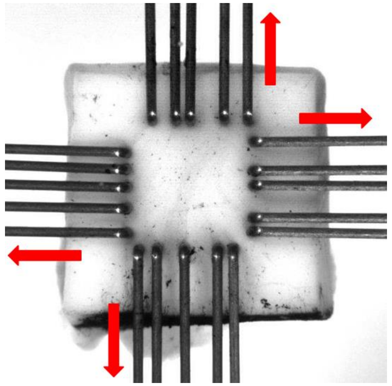
Methods

Normal Ascending Aorta	Aneurysmal Ascending Aorta
Organ donors not eligible for cardiac transplant (n=25) 	Patients treated for non-dissected ascending aortic aneurysms (n=102) Patients with available CT imaging (n=39) 

Ex-Vivo Biomechanics



Biaxial Tensile Testing



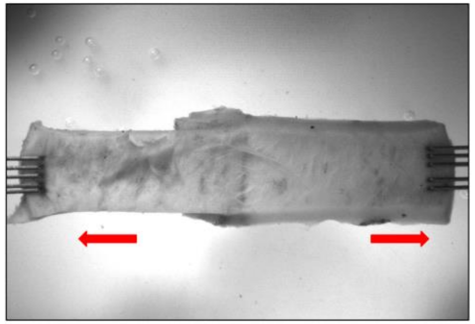
Energy Loss - measure of the efficiency of the aorta in performing the Windkessel function

Elastic Energy – measure of stored potential energy when elastin fibers are engaged

Low Tangent Modulus - measure of aortic stiffness

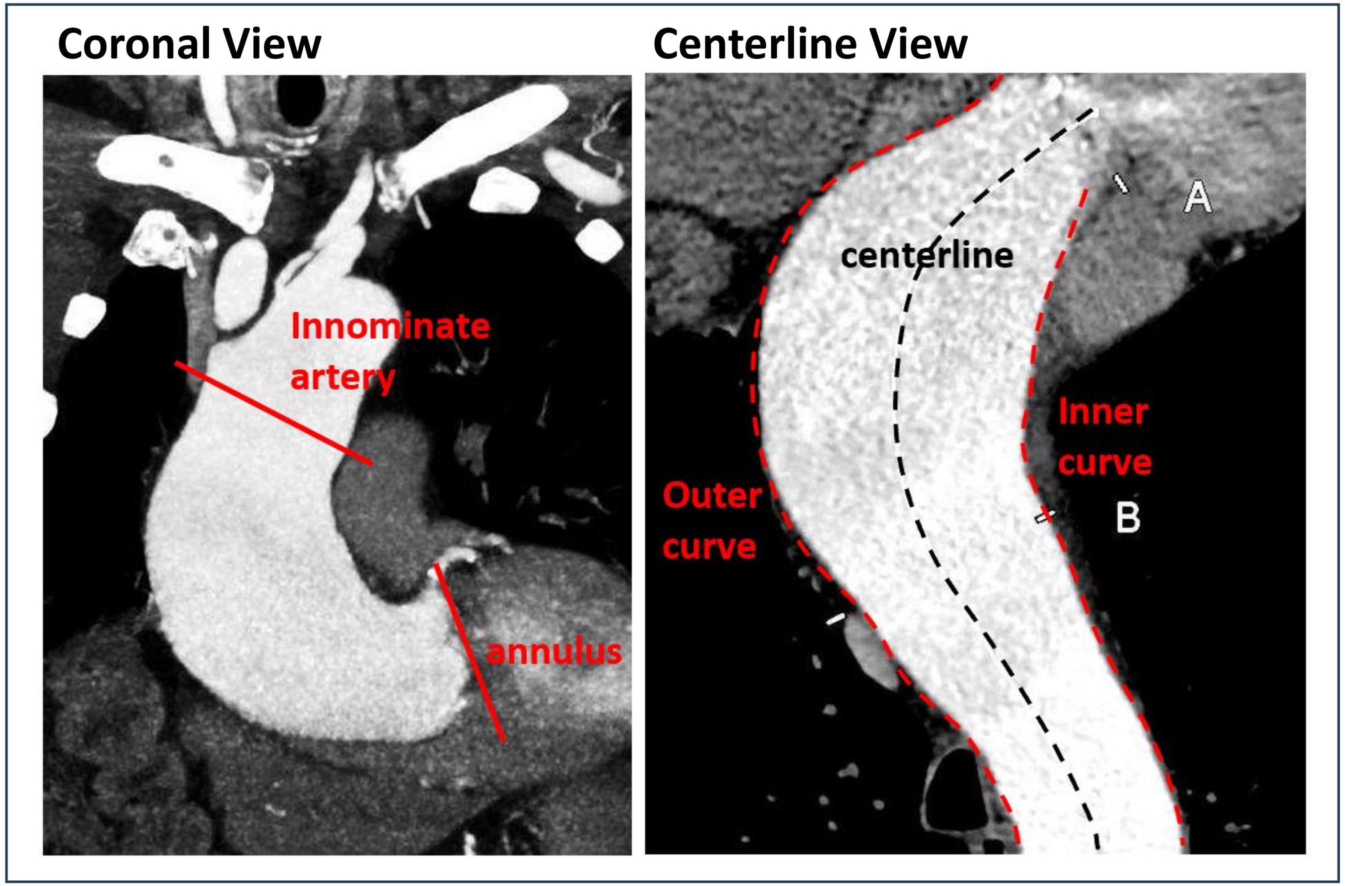
Stress/Strain @ Tzo – stress/strain at maximum elastin engagement

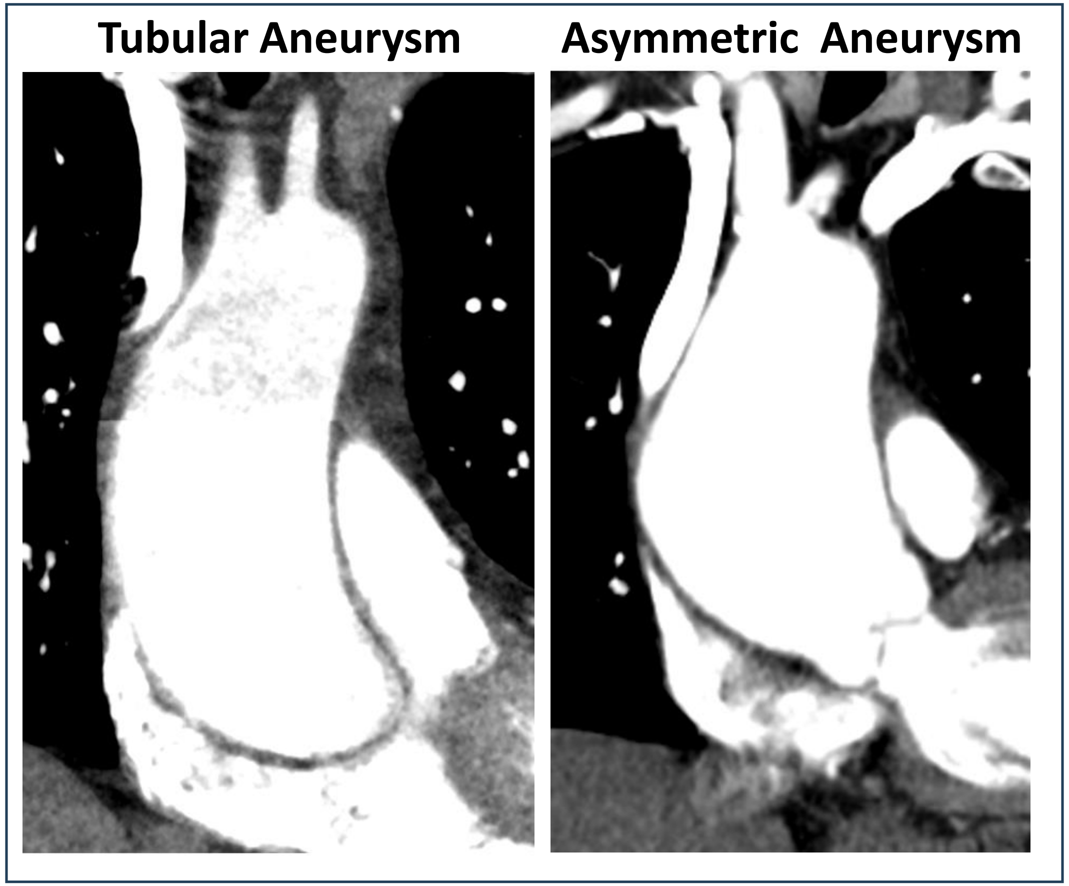
Delamination Testing



Delamination Strength – a measure of adhesion strength between aortic tissue layers

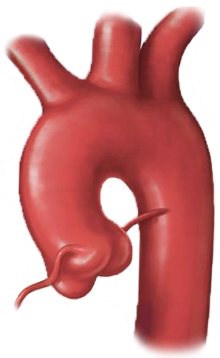
Centerline Analysis

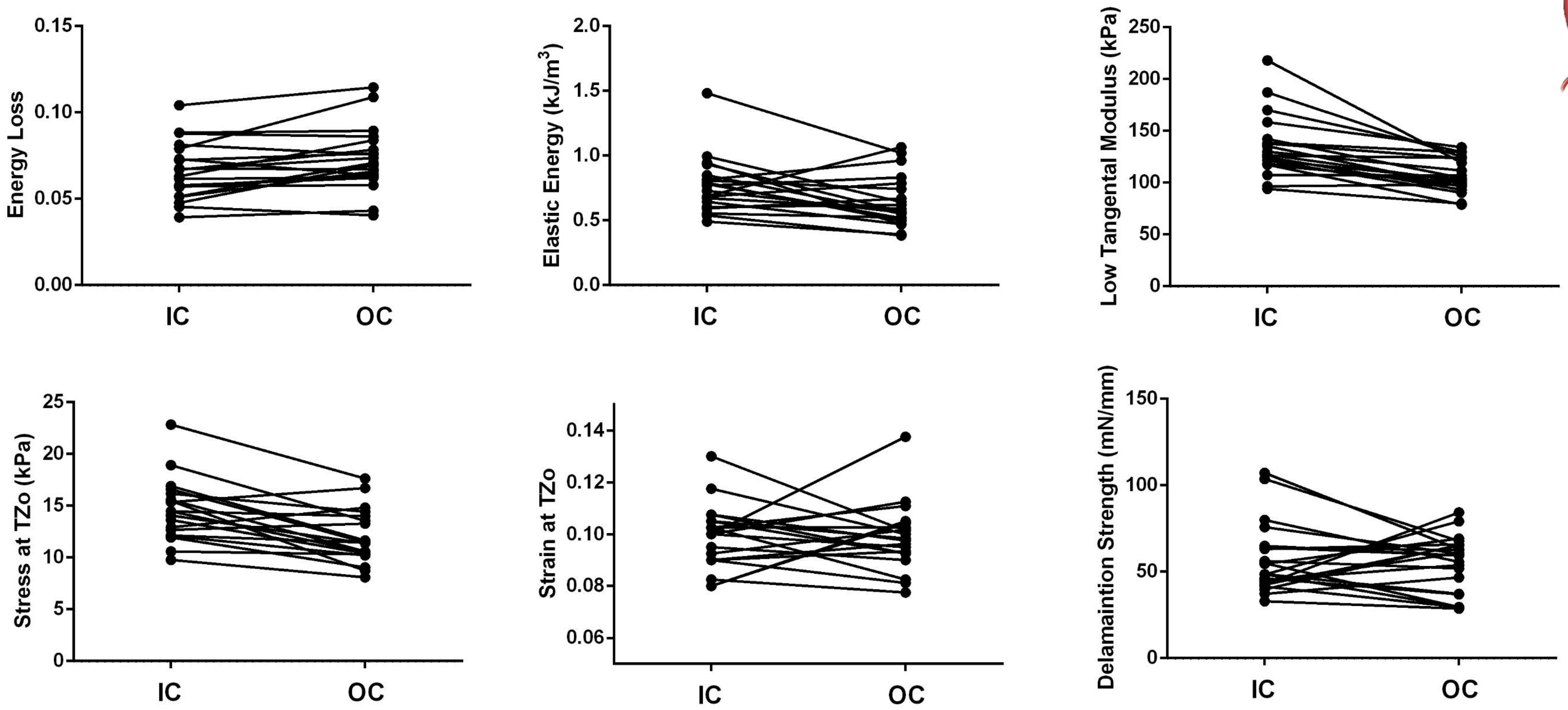




*Measured aortic dimensions taken between bottom of aortic annulus to proximal innominate artery.

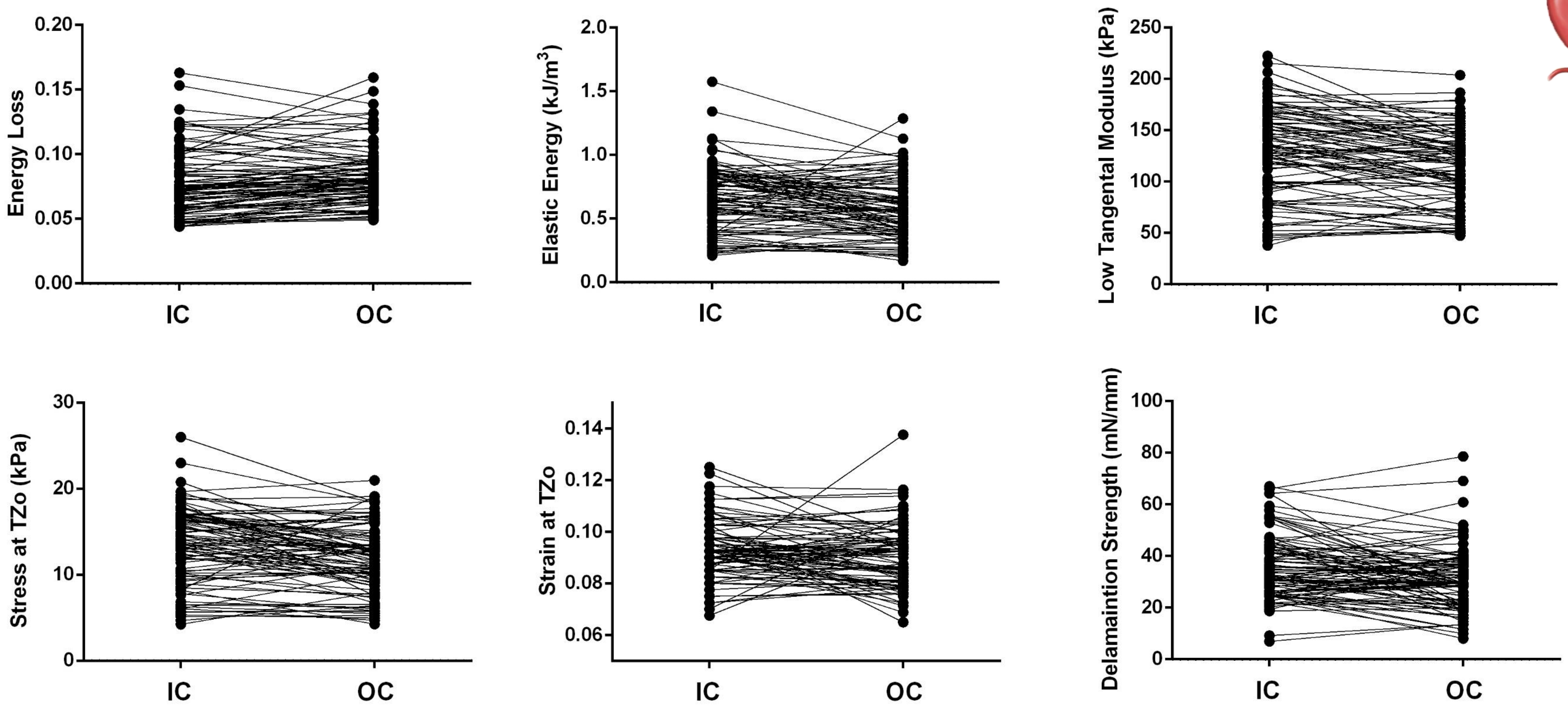
Results: Normal Aortas





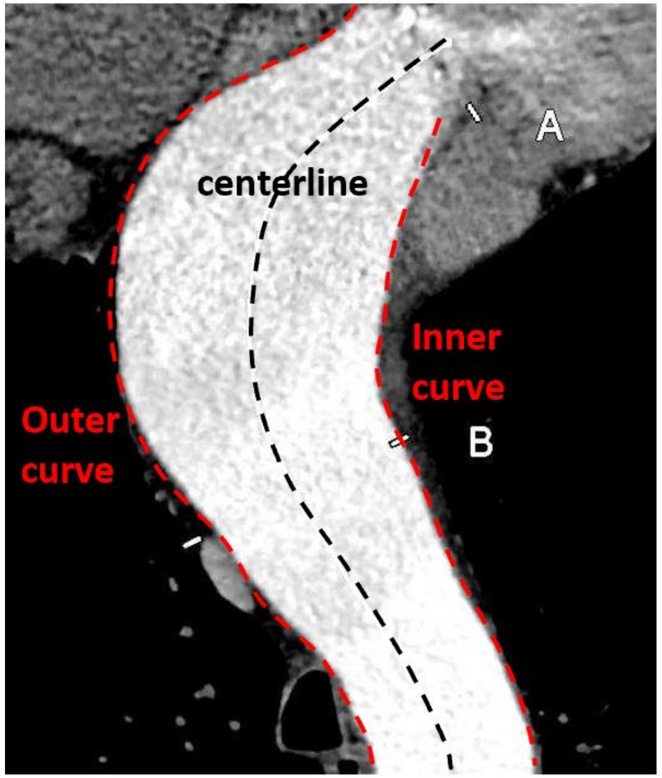
*Circumferential biomechanics displayed; similar results found when comparing longitudinal biomechanics.

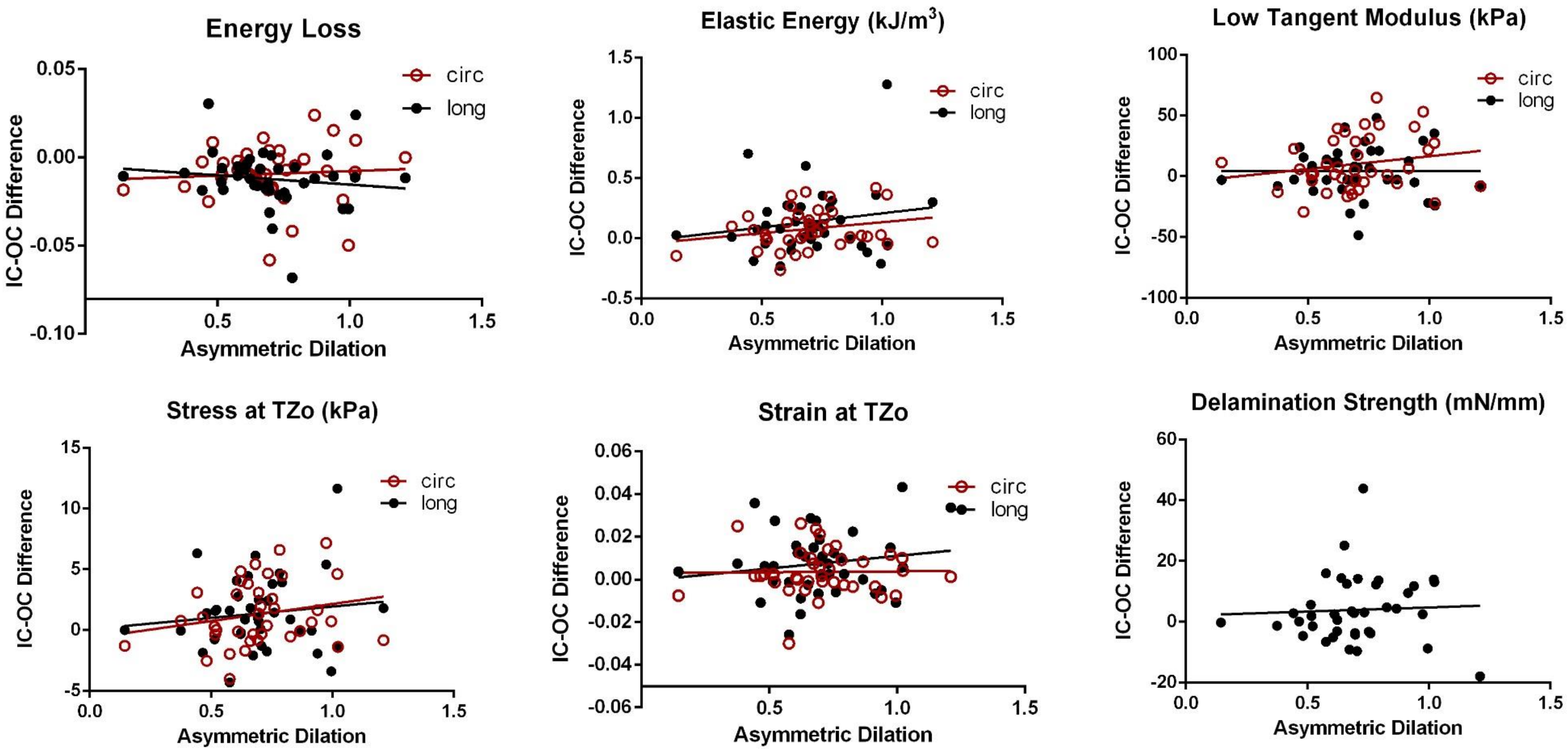
Results: Aneurysmal Aortas



*Circumferential biomechanics displayed; similar results found when comparing longitudinal biomechanics.

IC-OC Difference vs. Asymmetric Dilation





Asymmetric Dilation

$$= \frac{(\text{OC length} - \text{IC length})}{\text{Centerline Length}}$$

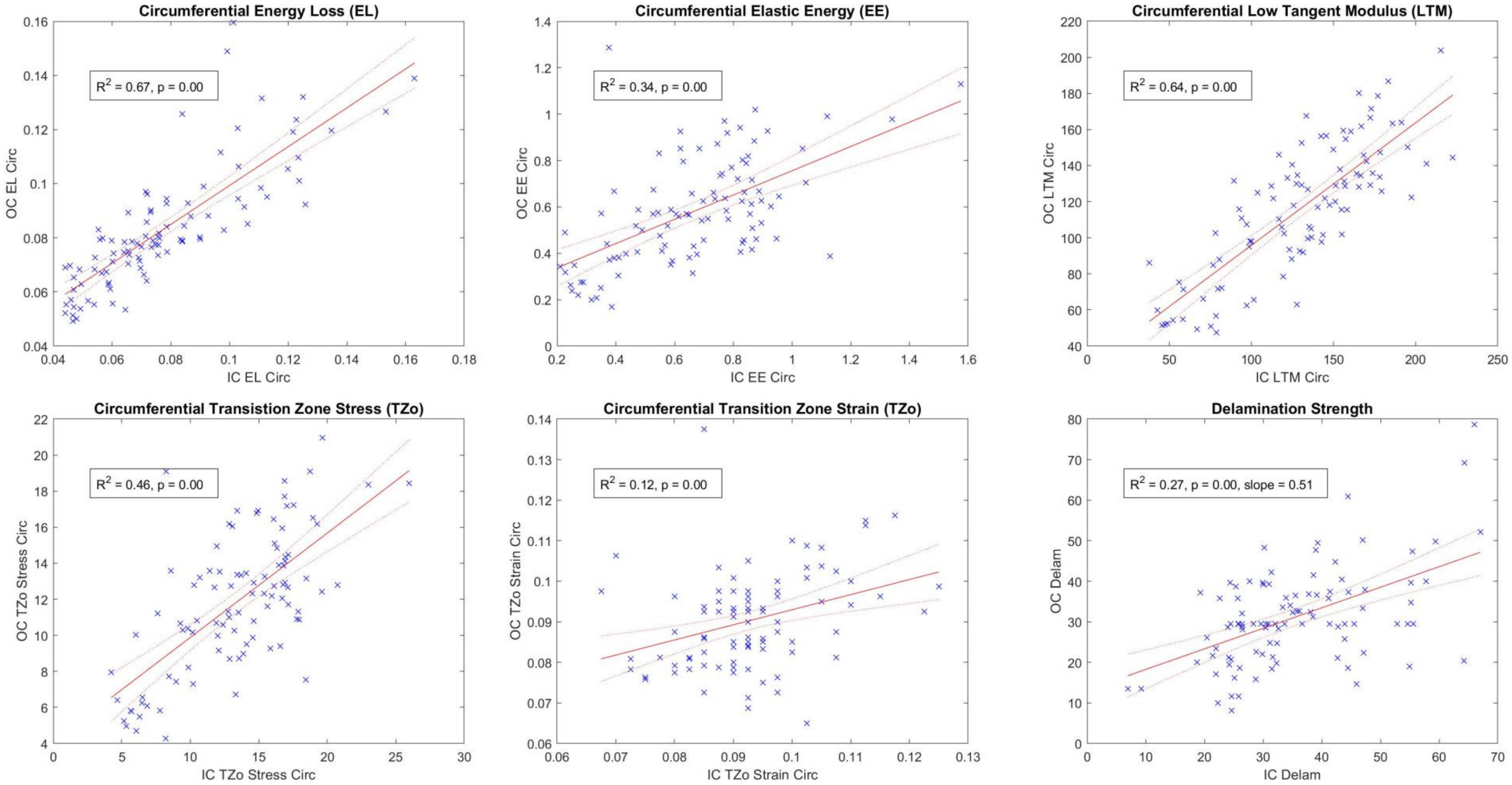
N.S. = Not Significant

IC-OC Difference vs. Clinical Variables

	Low IC-OC Difference N=87	High IC-OC Difference N=15	p-value
Age, Y	64 ± 14	72 ± 12	0.06
Male, %	69.0	66.7	>0.99
Diameter, mm	51.0 ± 8.0	55.0 ± 11.5	0.052
Asymmetry	0.67 ± 0.19	0.73 ± 0.19	0.17
Hypertension, %	58.6	66.7	0.76
Dyslipidemia, %	32.2	33.3	> 0.99
Diabetes, %	2.3	6.7	0.92
BAV, %	49.4	26.7	0.18
AV Insufficiency, %	50.6	60.0	0.69
AV Stenosis, %	34.5	20.0	0.42

*Low versus High IC/OC difference determined by interquartile range of biomechanical properties.

Linear Correlation between IC and OC Biomechanics



*Circumferential biomechanics displayed; similar results found when comparing longitudinal biomechanics.

Discussion and Conclusion

- Significant biomechanical differences between IC and OC regions were observed in a minority of both normal and aneurysmal aortas.
- Regional biomechanical differences were not predicted by clinical variables such as asymmetric dilation and presence of BAV.
- Biomechanical properties of the IC and OC regions were strongly linearly correlated.
- Therefore, global measures of biomechanics of the ascending aorta are valid for the majority of patients.